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DETERMINATION OF LANDING VISIBILITY AT AIRPORTS

V. A. Gavrilov and V. I. Goryshin

As is known, it is presently assumed that the problem of blind flying is basically solved. However, the final and most important stage of the flight — landing on the landing strip (LS) — has not been completed by the pilot using equipment, but by visual observation of the airports. /18*

Contemporary equipment for blind flying provides for the aircraft blind approach to the LS following along the landing beam, up to 1000 - 500 m from the beginning of the LS, after which the pilot changes to visual flying. The so-called equipment to be used for blind landing in actuality does not provide blind landing. As of the present, blind landing is still in the experimental stage, and until recently it was the most important unsolved problem of aeronautical navigation. The problem of blind landing, which does not depend on meteorological equipment, clearly lags behind general technological progress in aviation.

The safe landing of aircraft, and even the normal operation of airports, depend on the state of atmospheric transmittance and the height of the lower cloud boundary, which determines the visibility range of the beginning of the LS. With poor visibility, the visibility range of the LS beginning for the pilot, following a landing beam, is called the landing visibility range, or simply

*Numbers in the margin indicate pagination of original foreign text.

the landing visibility. When we are speaking of the visibility range of a certain object (including the LS beginning) this refers to the distance to the object at which it can be observed with very faint (threshold) recognition. Therefore, we may discuss the concept of landing visibility as follows.

The term landing visibility S_l is used to describe the maximum distance to the beginning of the LS, at which the pilot following a landing beam can see and recognize the LS beginning /19
with threshold recognition in the case of poor visibility.

In the daytime, the numerical value of the landing visibility depends on the state of atmospheric transmittance, expressed by the meteorological visibility range S_M and the photometric (brightness) properties of the LS and the background surrounding it.

In addition, the numerical value of S_l is influenced by the brightness of the clouds (fog) and the visual properties — the contrast sensitivity threshold.

The theory of visibility range as applied to landing visibility combines all of these factors into the equation

$$S_l = 0.66\, S_M \lg \frac{\frac{K_0}{\varepsilon} + \left| \frac{B}{B_0} - 1 \right|}{\frac{B}{B_0}} \qquad (1)$$

Here S_M is the meteorological visibility range, $\left.\frac{K_0}{\varepsilon}\right|$ — LS visibility coefficient on a given background (in the absence of clouds) which represents the ratio of the real contrast between the LS and the background surrounding it to the quantity ε of the visual contrast sensitivity threshold, and B/B_0 is the ratio of the cloud brightness (fog) in a layer of differing visibility range to the LS brightness.

It is naturally correct to determine S_l on the basis of this relationship which is logically derived (and not empirically), since it takes into account all of those factors which influence the landing visibility.

Up to the present, in practice landing visibility is still not being determined in accordance with Expression (1). Pilots who are landing are only given the meteorological visibility range by the equipment at airports.

This may be greatly explained by the fact that the concept of landing visibility and the necessity of correctly determining it was formulated comparatively recently, 8 - 10 years ago. Since this time, a theory, equipment, and methods for measuring the parameters determining landing visibility have been developed, and the problem of determining landing visibility in the daylight is now assumed to be basically solved.

The M-37 transmittance indicator (meteorological visibility range) of the V. I. Goryshin system for determining S_M at airports, has been developed and been put into mass production.

The values of S_M are continuously recorded and written down by means of the transmittance indicator, located close to LS.

It is assumed that it is inappropriate to determine S_M by any other method except the indicators.

In addition to the transmittance indicator, it has been possible to develop a method for measuring the parameters K_0/ε and B/B_0 by means of visibility meters. As applied to concrete LS, these parameters are carefully measured for a long period of time for different seasons of the year and for different states of the LS surface and the background. The measurements are performed both on the ground and in the air. It has been found that changes in these parameters have primarily a seasonal matrix. Therefore, when measuring S_l it is not necessary to determine them each time anew. In final form, S_l is determined according to a nomogram.

To make a nomogram from (1), the following term

$$0.66 \lg \frac{\frac{K_0}{\varepsilon} + \left| \frac{B}{B_0} - 1 \right|}{\frac{B}{B_0}} \qquad (2)$$

is factored out, which is called the conversion factor from S_M to S_l. This coefficient expresses the influence of the parameters K_0/ε and B/B_0 on the LS degree of visibility. The conversion factor from S_M to S_l changes as a function of the time of year, and depending on whether the window in the aircraft cabin is dry or wet.

Giving the values of S_M and multiplying then by the determined values of the conversion factors, corresponding to the given season and the state of the window, we obtain a group of straight lines in a rectangular coordinate system.

Figure 1a, b gives two diagrams for determining S_l for a dry and wet window.

The values of S_M shown by the indicator are plotted along the ordinate axis, and the values of S_l in meters are plotted along the abscissa.

Combining the transmittance indicator readings with one of the lines (in accordance with the state of the background indicated on them) and projecting the point of intersection on the abscissa axis, we obtain the value of S_l on it.

Example. The transmittance indicator shows 1000 m. The background surrounding the LS is yellow grass. The LS is dry. According to the report of the pilot landing the aircraft, it is known that the sighting window is dry.

On the nomogram in Figure 1a, let us combine the indicator reading with the line on which the "background: yellowish brown grass" is given. We shall project the point of the intersection on the abscissa according to which we find that S_l equals 550 m. The instructor for the pilot gives the pilot the value of S_l, and, in accordance with the type of aircraft and the class of pilot — completes or does not complete the landing, using the existing landing norms.

This is the practical way of determining S_l in the daytime. However, it has one essential drawback: since the transmittance indicator characterizes the atmospheric turbidity in the horizontal direction, but in actuality it is necessary to know the turbidity with respect to the inclination along the landing beam

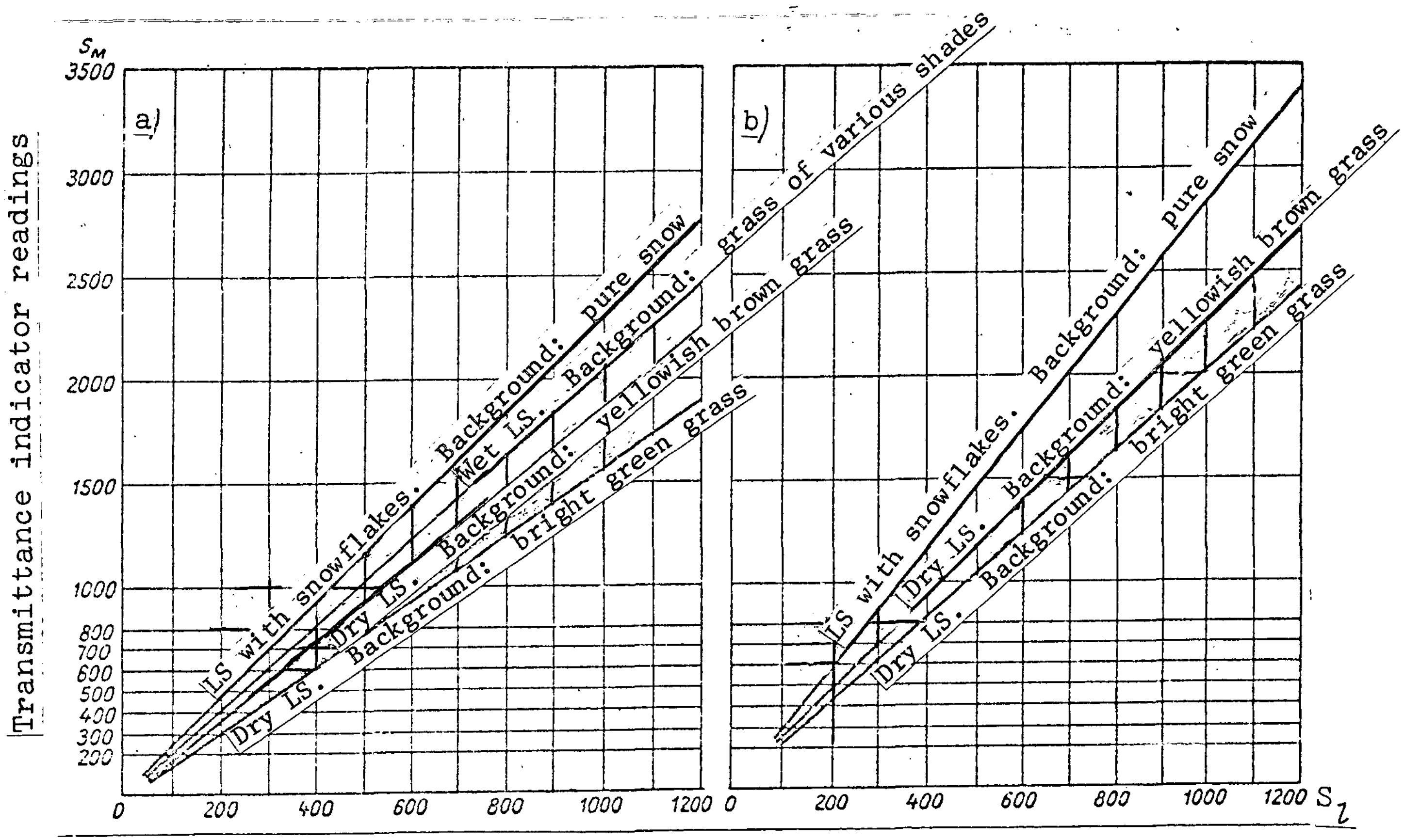

Figure 1. Graph of converting from S_M to S_l.

a — dry sighting window; b — wet sighting window.

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(2 - 5° angular altitude), this method is based on the assumption that the atmospheric turbidity is the same in these directions.

It may be seen from the graphs in Figure 1a, b that the value of S_l may differ greatly from S_M. This is due to the fact that the conversion coefficients (2) are much less than unity. However, there is a simple method of raising these conversion coefficients to 1 and then reducing S_l to S_M. This is a system of marking the LS.

In our opinion, Figure 2 shows the most efficient system for marking the LS. It does not require any special explanations. We need only note that the marking would have the great advantage of:

(1) increasing the value of S_l for one and the same values, which would greatly expand the operational possibilities of the airport in the case of deteriorating visibility,

(2) enabling the pilot to better recognize the LS beginning, which would facilitate landing conditions in the case of poor visibility,

(3) simplifying the method of determining S_l,

(4) making the marking of the LS more visible at night /22
when illuminated by aircraft flares or by landing lights.

In conclusion, let us make a few remarks about determining landing visibility at night.

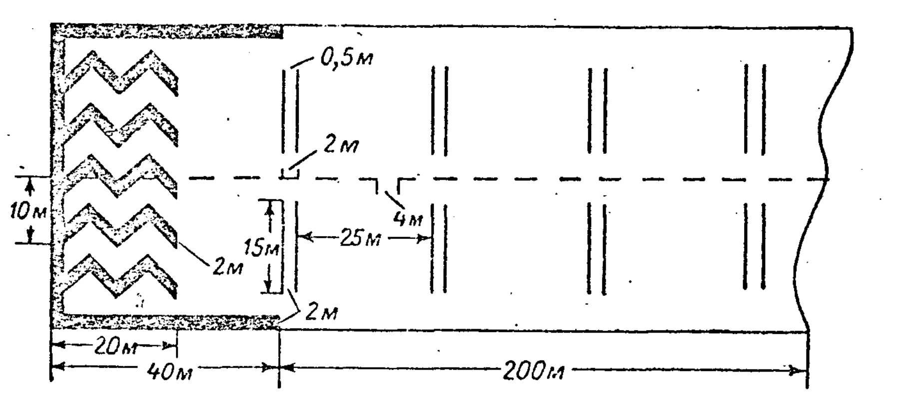

Figure 2. LS marking diagram.

The landing strips of contemporary airports are equipped with a complex system of numerous signal lights, which may be divided into approach lights and safety lights.

The term landing visibility at night designates the distance with respect to the inclination along the landing beam at which the pilot landing the aircraft, when changing from instrument flying to visual flying, can see a certain number of lights (with limiting threshold recognition) in accordance with the existing landing norms.

Thus, landing visibility range at night is connected with the visual threshold recognition of grouped lights.

The following formula may be used to determine the visibility range $S_{l\ (H)}$ of grouped lights at night

$$\ln S_{l\ (H)} + \frac{3.5}{2S_M} S_{l\ (H)} = \frac{1}{2} \ln \frac{I}{E_{li}}$$

Here S_M is the meteorological visibility range determined by the transmittance indicator, I — luminous intensity of the lights, E_{li} — visual light sensitivity threshold for grouped lights.

There are still no reliable data on the rules governing the recognition of grouped lights. There is no great difference between the values of E_{li} for one light or for grouped lights.

In the presence of strong atmospheric turbidity, powerful grouped lights may produce unusual light phenomena — bright halos around the light sources. In the case of airport lights, the halos arising around each light source may merge together, forming a bright band of variable brightness, which is brighter, the greater is the atmospheric turbidity. In view of this, E_{li} has a differing value for grouped lights: the smaller the atmospheric transmittance, the greater is the value of E_{li}, and the less visible are grouped lights. It is an extremely important problem to determine the background brightness as a function of S_M and to find the values of E_{li} in connection with this for grouped airport lights.

The Main Geophysical Observatory and the State Scientific Research Institute of the Civil Air Fleet are performing a concurrent study of E_{li} for grouped lights. /23

With reliable values of E_{li}, $S_{l\ (H)}$ will be determined for grouped lights by nomograms, similarly to the nomograms of Figure 1a and b.

For those readers who are interested, we refer them to [1], which gives several nomograms of this type. As a means of refining E_{li} for grouped lights, they may be recommended as only provisional for aircraft landing.

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